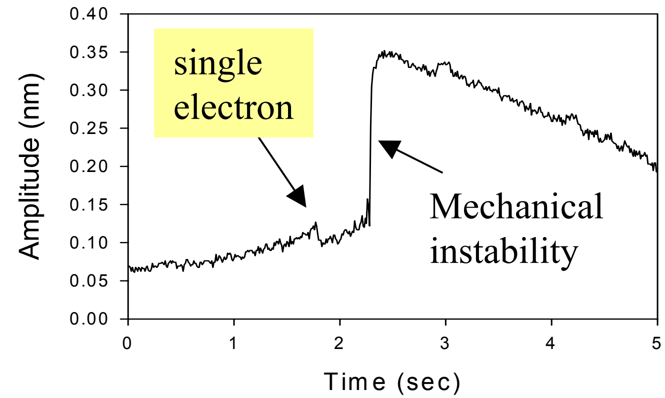
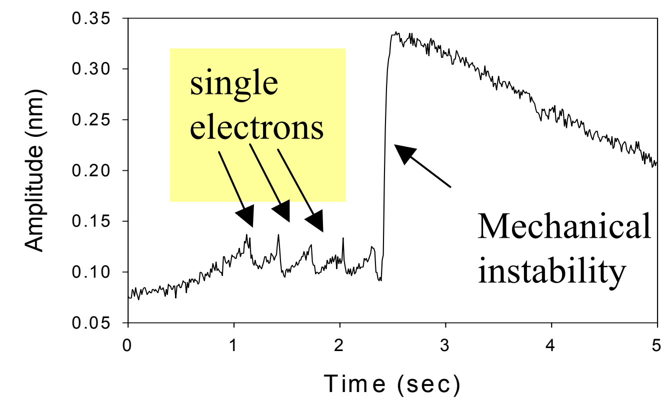
Single electron tunneling observed

The Scanning Tunneling Microscope (STM) has had a tremendous impact in nanometer scale science and technology. However, non-conducting surfaces cannot be imaged by the STM because typically pico-ampere currents (~10^7 e / sec) are needed to perform the imaging. Thus, isolated electronic states, with lifetimes greater than ~ 0.1 microsecond cannot be directly imaged by STM.

With support from NSF, a **force based** method has been developed at the University of Utah to **detect single electron tunneling events** between a conducting scanning probe tip and a insulating sample surface. When an electron tunnels to or from an oscillating, voltage biased tip, the electrostatic force on the tip changes. This force change is detectable as an abrupt change in amplitude or frequency of the oscillation, even when a single electron tunnels, as shown in the figure to the right.



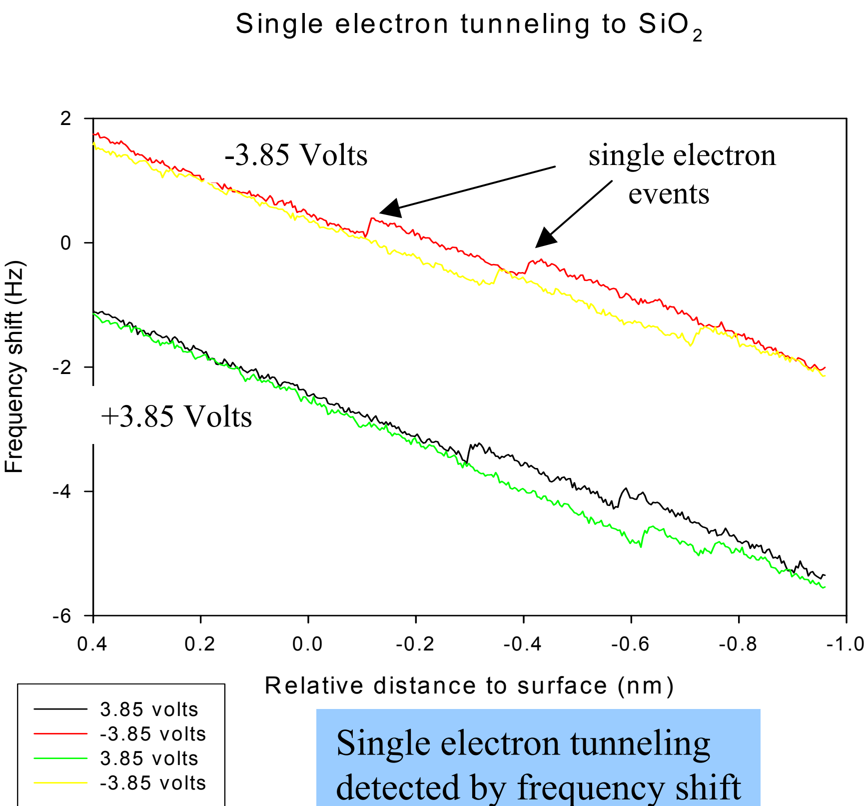


Cantilever amplitude as the tip is scanned toward a 20 nm oxide on silicon. When the tip reaches tunneling range, single electron tunneling events are observed before the tip/sample gap becomes unstable.

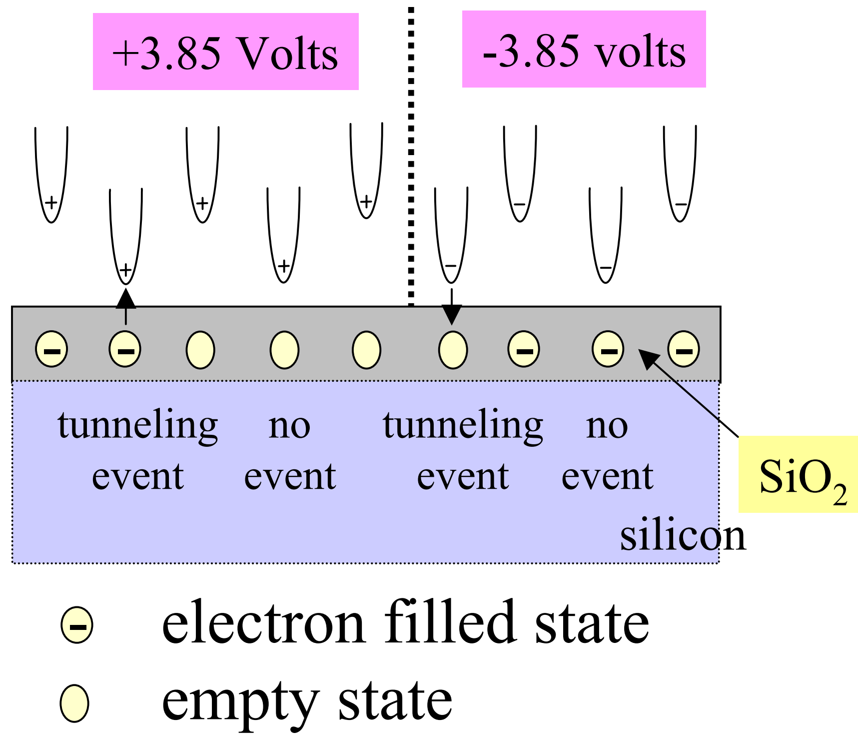
C.C. Williams, U. of Utah

Single electron manipulation by reversible tunneling to trap states

Single electrons are shuttled to/from an SiO_2 surface by reversing the tunneling bias. When a positive tip is brought near a filled state, a tunneling event is seen (emptying state). When positive tip returns to this empty state, no tunneling is observed. Upon reversal of the tip bias (negative), tunneling is observed to the now empty state, but upon second approach with negative bias, no event is observed. Manipulation and control of single electrons will be important for future nanometer scale devices and for characterizing insulating materials / molecules on an atomic scale.



Single electron tunneling detected by frequency shift



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